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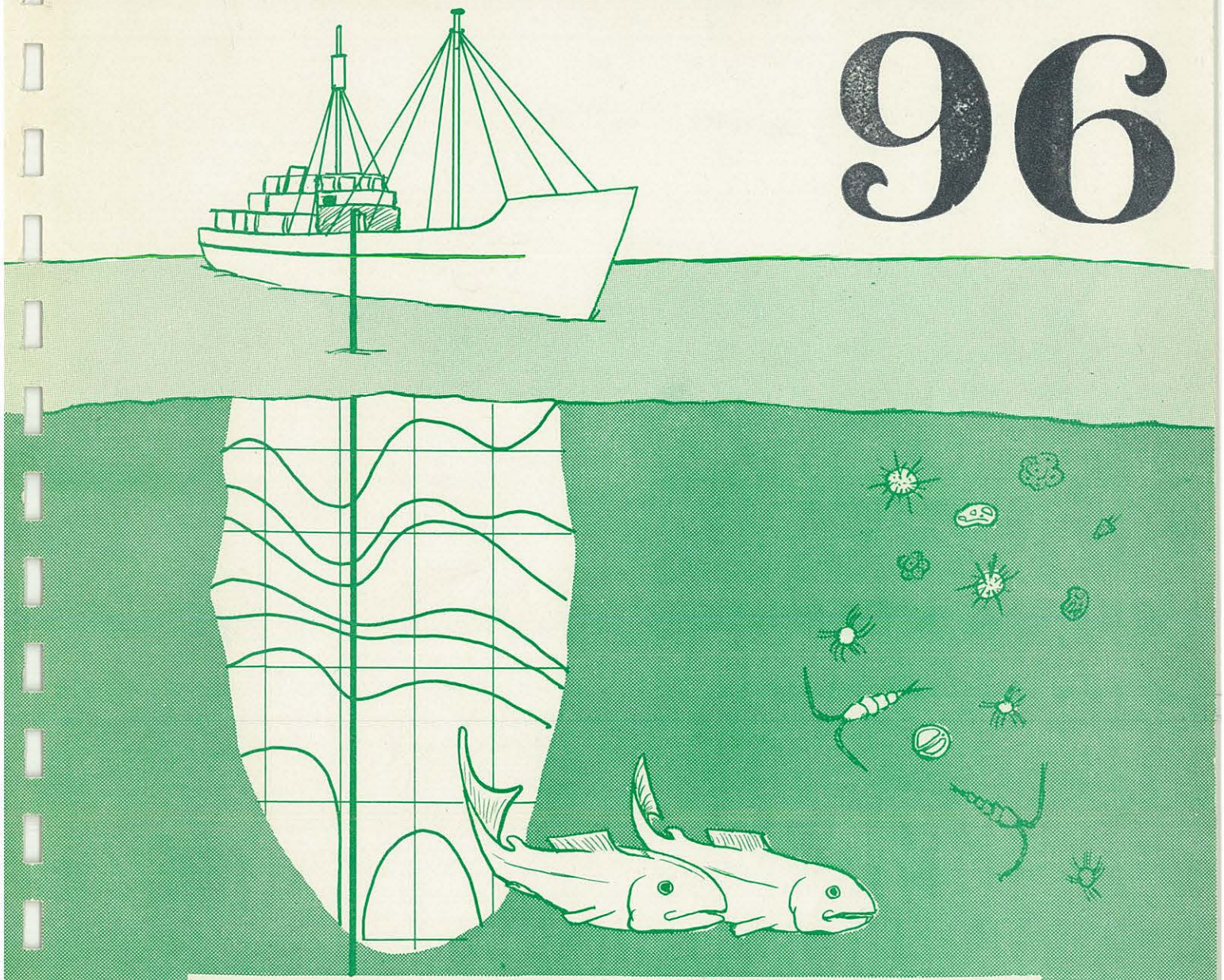

RELATIONSHIPS BETWEEN SALMON DISTRIBUTION AND ENVIRONMENT
IN THE CENTRAL NORTH PACIFIC OCEAN
DURING AUTUMN 1965

by

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INPFC Document No. 922

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October 18, 1966

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INTRODUCTION

The objective of oceanographic research conducted by the United States for the International North Pacific Fisheries Commission is to forecast the salmon distribution in the North Pacific Ocean from an understanding of the environmental conditions. Major physical oceanographic features of the Subarctic Pacific Region are relatively constant (Dodimead, Favorite and Hirano, 1963); the nature of oceanographic research has changed from general exploratory surveys over large areas to specific and more detailed investigations, and to studies of seasonal changes. The realization that conditions during spring cannot be predicted accurately without a knowledge of changes during the entire year has led to fishery-oceanography cruises during all seasons. Favorite (1965) demonstrated significant relationships between the temperature and salinity structure and the salmon distribution during winter and spring. Favorite and Hanavan (1963) found significant relationships during spring and summer.

The cruise of the U.S. Bureau of Commercial Fisheries RV George B. Kelez in the central North Pacific Ocean was designed to investigate relationships between the distribution of immature salmon and oceanographic features during October and November, 1965; few data are available for autumn. During previous cruises, fishing sets were normally 60 miles apart; oceanographic stations were obtained at each set, but between sets only when time permitted.

Because the major oceanographic features were known previously from the distribution of temperature and salinity, bathythermograph (BT) lowerings and surface water samples were taken at 10-mile intervals during the autumn cruise and analyzed aboard the vessel to determine the location of significant changes in these properties. The positions of oceanographic stations and gill net sets were determined by variations in the temperature structure and surface salinity along two principal cruise tracks--long. 173° E. and lat. 50° N. (fig. 1). Gill net sets and oceanographic stations were made at night in the zones of uniform temperature structure; oceanographic stations were made between sets to determine the nature of changes in water mass and the current structure near boundaries. Additional oceanographic stations south of Adak Island were closely spaced to determine velocity and transport in the Alaskan Stream; no fishing sets were made in this area.

OCEANOGRAPHIC CONDITIONS

Long. 173° E.

Three current systems, two water masses, and several distinct features of the distribution of properties were encountered during the cruise track along long. 173° E. Their identification provides a general review of the major features of the Subarctic Pacific Region and shows conditions which existed during autumn, 1965.

Geostrophic currents represent the average current velocity between oceanographic stations, and may not reflect either maximum currents or exact boundaries between current systems, since narrow current bands may be missed in sampling and additional uncertainties occur because geostrophic velocities less than 2 cm./sec. are not significant. A vertical section of geostrophic

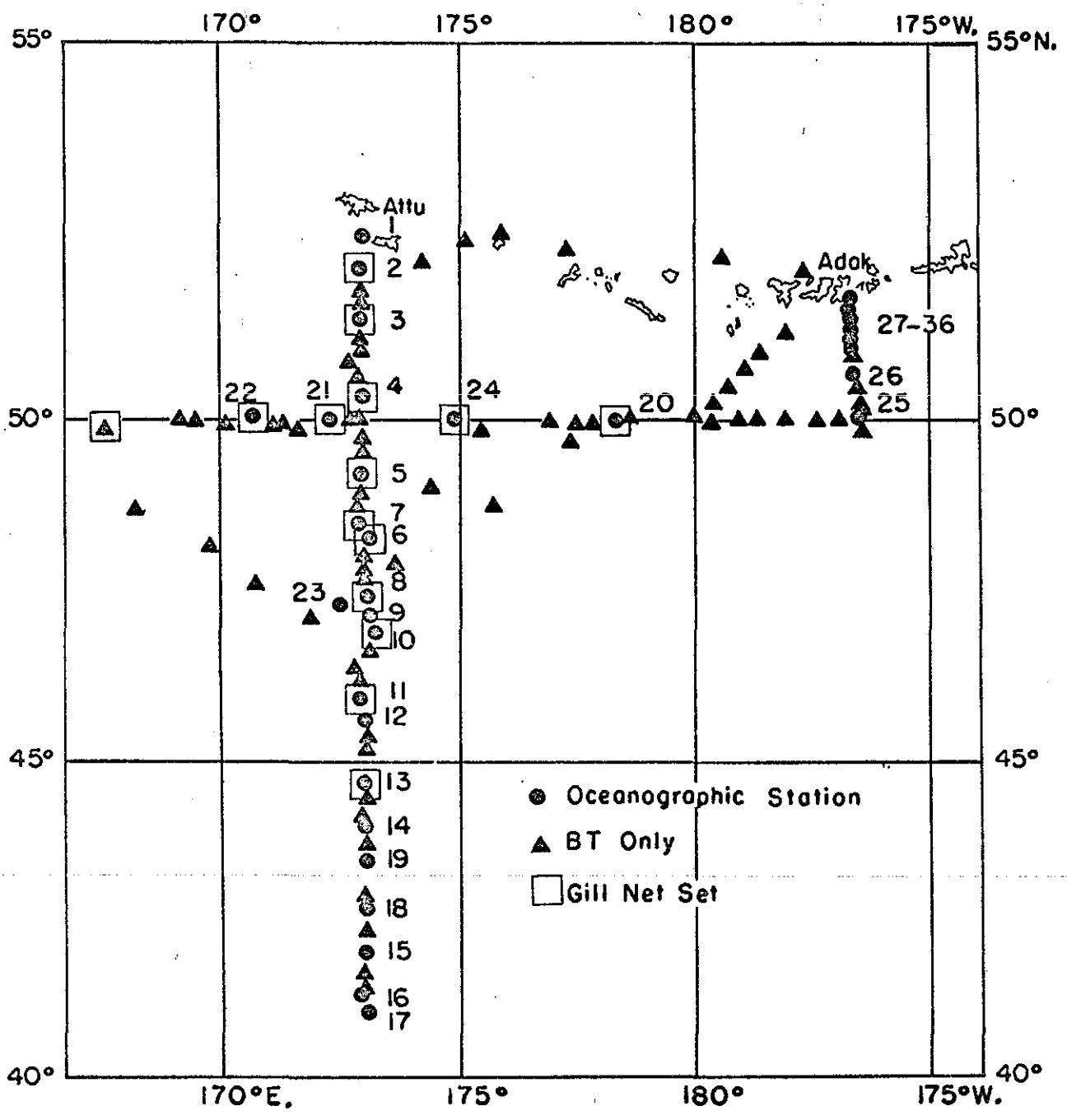

Figure 1.--Locations of oceanographic stations, BTs, and gill net sets, RV George B. Kelez, October and November 1965.

velocities across long. 173° E. between Attu Island and lat. 41° N. (fig. 2) shows three significant areas with high velocities. The Alaskan Stream flowed westward slightly south of Attu Island with a maximum speed greater than 14 cm./sec. (6.5 miles/day). Farther south, eastward velocities in excess of 10 and 18 cm./sec. (4.7 and 8.4 miles/day) are axes of the Subarctic Current and West Wind Drift, respectively.

The Subarctic and Subtropic Water Masses, which are differentiated on the basis of temperature and salinity relationships, are shown in vertical sections of these properties along long. 173° E. (fig. 3). The Subarctic-Subtropic Boundary or the nearly vertical 34.0 °/oo isohaline is a relatively permanent feature which extends across the North Pacific Ocean near lat. 42° N., but the boundary had apparently shifted northward to near lat. 43° N. by autumn, 1965.

Within the Subarctic Water Mass the isolines of temperature and salinity at depth denote several distinct features which are relatively permanent. The primary feature of both the isotherms and isohalines is the distinct ridge structure which appeared to crest near lat. 50° N. Westerly flow is generally associated with the northern side of the ridge; easterly flow with the southern side.

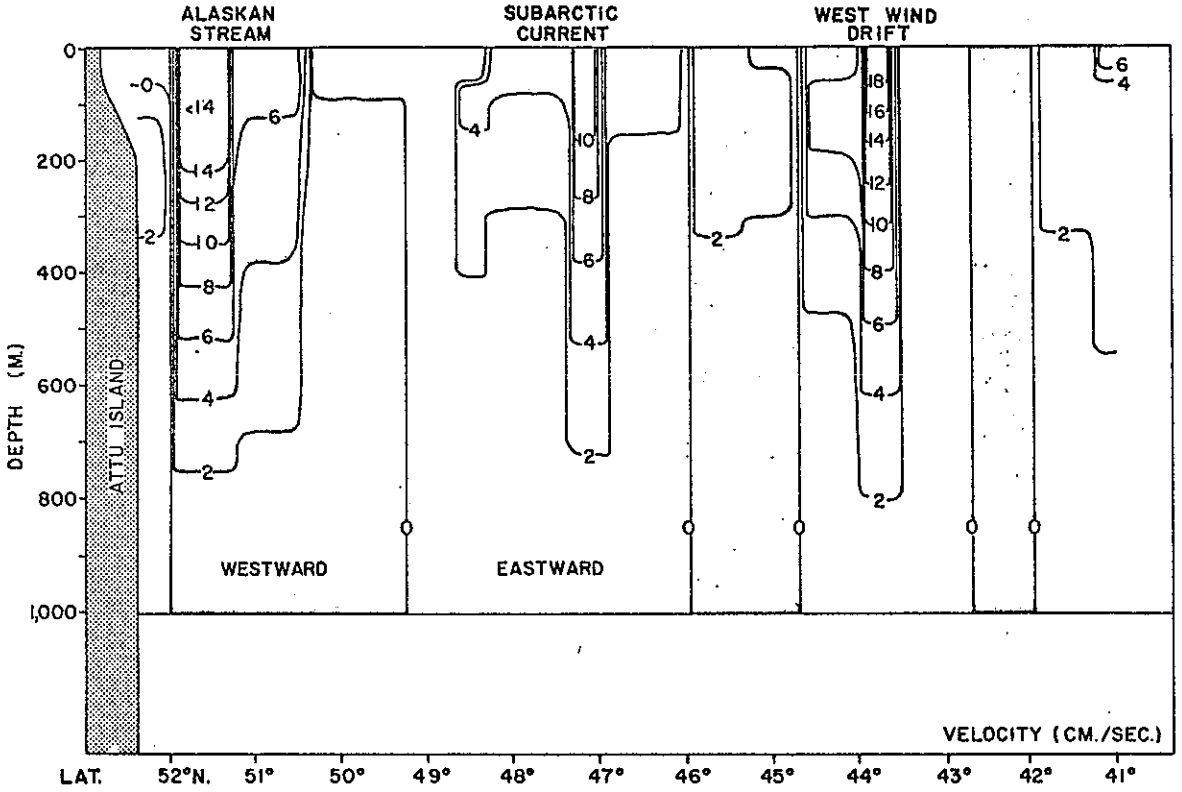

Figure 2.--Vertical section of geostrophic currents (cm./sec.) relative to 1,000 db. along long. 173° E.

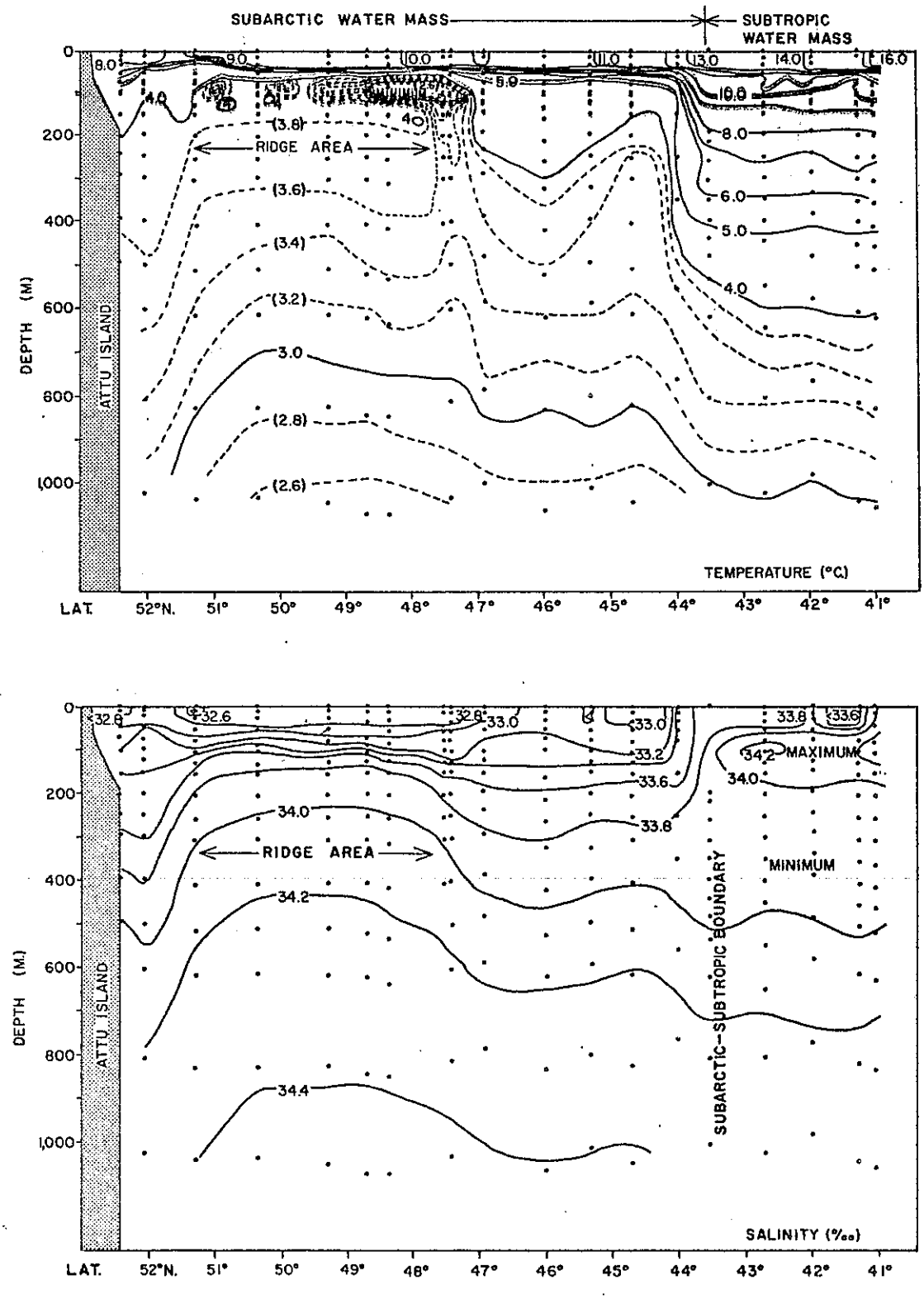

Figure 3.--Vertical sections of temperature (°C.) and salinity (°/oo) along long. 173° E.

Major features of the temperature distribution were closely associated with the major current systems and their boundary areas. The downward slope of the 4.0° C. isotherm near lat. 51° N. coincided with the swiftly flowing axis of the Alaskan Stream; the ridge area with relatively level isotherms possessed weak, variable currents near the boundary between westward and eastward flow. The northern boundary of the cold temperature-minimum, less than 3.0° C. at 100 m., coincided with the first significant eastward flow south of the central Aleutian Islands; the downward slope of the 4.0° C. isotherm near lat. 47° N., with the axis of the Subarctic Current; and the downward slope of the 4.0°, 5.0°, and 6.0° isotherms below 200 m. at the Subarctic-Subtropic Boundary, with the maximum geostrophic flow of the section in the axis of the West Wind Drift.

Lat. 50° N.

Data from oceanographic stations along lat. 50° N. indicated conditions were quite uniform and similar to those in the ridge area near lat. 50° N. along long. 173° E. A vertical section of geostrophic currents is not presented because velocities along lat. 50° N. did not exceed 2 cm./sec. There is no substantial north-south flow throughout the boundary area between the Alaskan Stream and the Subarctic Current. A vertical section of salinity along lat. 50° N. (fig. 4) shows relatively level isohalines and continuity of the ridge area between long. 170° E. and 176° W. This is also shown by the depth of the 34.0 °/oo isohaline which did not exceed 300 m. along lat. 50° N. The temperature structure along lat. 50° N. was also similar to that in the ridge area and will be discussed in relation to the salmon distribution.

Long. 176°25' W.

A large discrepancy was reported between direct current measurements (50 to 100 cm./sec.) and calculated geostrophic currents (10 to 30 cm./sec.) for the Alaskan Stream (Favorite, 1966). Oceanographic stations were therefore obtained at 5 mile intervals across the Stream south of Adak Island to determine if the discrepancy was caused by the large distance (30 to 60 miles) between oceanographic stations used in the previous calculations.

Geostrophic current calculation (fig. 5) confirmed the presence of westward velocities exceeding 40 cm./sec. (18.7 miles/day) relative to 1,000 db. The maximum velocity occurred between 100 and 200 m. depth close to shore in a narrow stream about 10 miles wide.

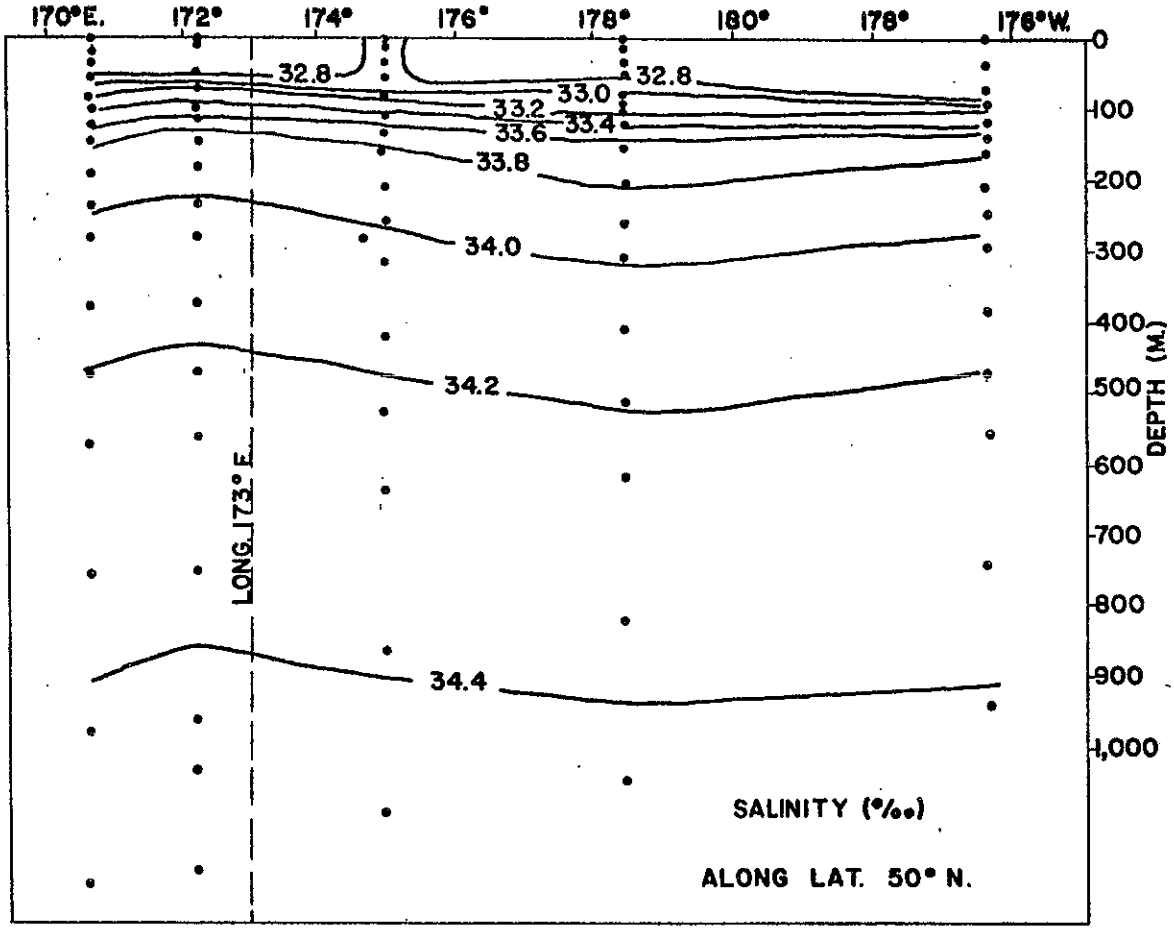

Figure 4.--Vertical section of salinity (°/oo) along lat. 50° N.

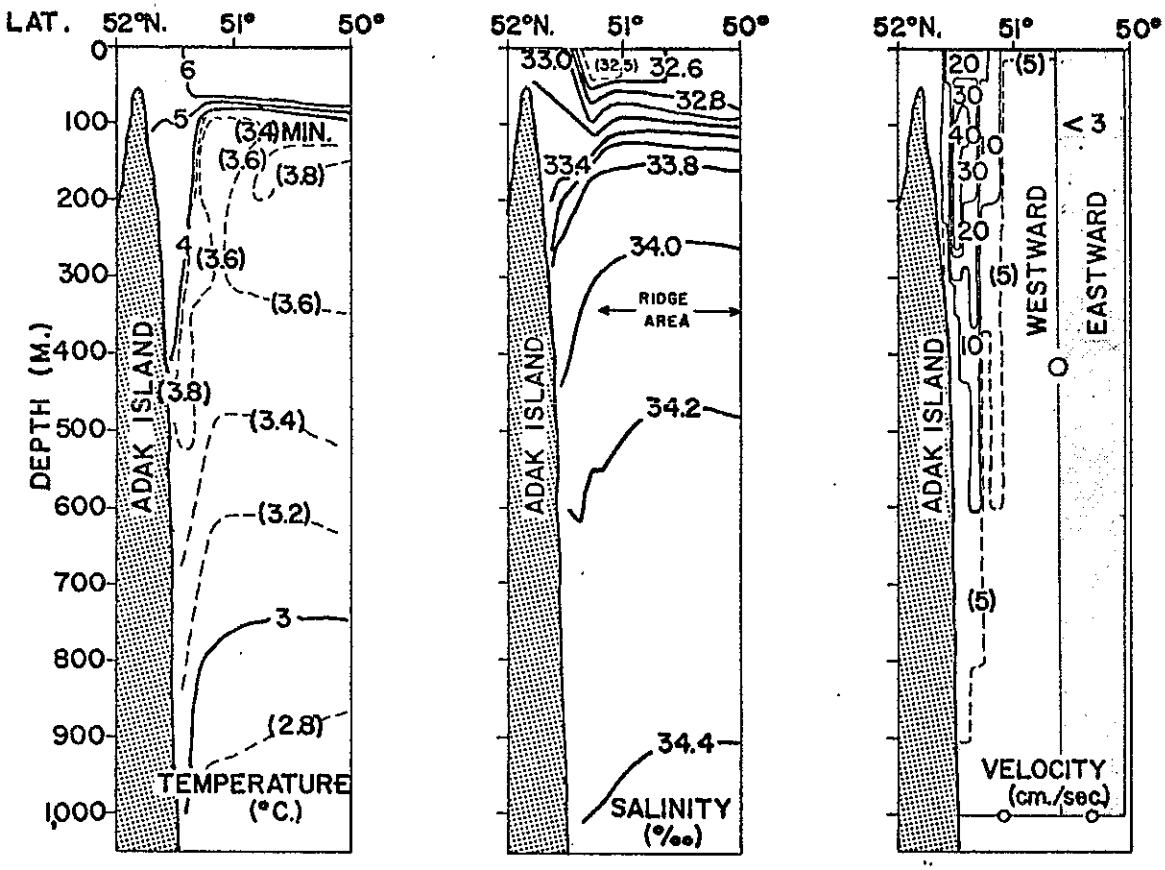

Figure 5.--Vertical sections of temperature (°C.), salinity (°/oo), and geostrophic velocity (cm./sec.) along long. 176°25' W.

A vertical section of temperature (fig. 5) showed the 4.0° C. isotherm sloped downward from 100 to 400 m. near shore; a vertical section of salinity (fig. 5) showed a similar depression for the isohalines in the same depth range. Weak geostrophic currents, 5 cm./sec., were again associated with the relatively level isolines in the ridge area near lat. 50°30' N. The distribution of properties therefore indicated the same features were continuous between Adak and Attu Islands, but the axis of the Alaskan Stream was farther offshore south of Attu Island than Adak Island.

Summary of Oceanographic Conditions

Oceanographic data collected during autumn, 1965, along long. 173° E. between Attu Island and lat. 41° N. indicated the Subarctic-Subtropic Boundary had shifted slightly northward from lat. 42° N. to lat. 43° N., but the locations of the other major oceanographic features had not changed significantly from previous observations in 1959.

Calculated geostrophic currents indicated the high velocity axes of the major current systems coincided with distinct features of the temperature distribution: the Alaskan Stream flowed westward at 14 cm./sec. near lat. 51° N.; the Subarctic Current flowed eastward at 10 cm./sec. near lat. 47° N. and the West Wind Drift flowed eastward at 18 cm./sec. near lat. 43° N. The configuration of the deep isotherms and isohalines indicated a distinct ridge structure between the axes of the Alaskan Stream and the Subarctic Current, and the relatively flat isotherms near the crest of the ridge at lat. 50° N. were associated with very weak currents near the boundary of the westward and eastward flows. The relatively uniform distribution of salinity along lat. 50° N. indicated this ridge was continuous.

The Alaskan Stream possessed very similar temperature and salinity structures along long. 173° E. and along long. 176°25' W., but maximum geostrophic velocities were three times greater (40 cm./sec.) along long. 176°25' W. where stations were obtained across the stream at 5-mile intervals. This suggests closely spaced oceanographic stations across the Alaskan Stream are necessary to obtain a reliable estimate of the velocity structure of the Alaskan Stream.

RELATIONSHIPS BETWEEN OCEAN CONDITIONS AND SALMON CATCH

The temperature distribution in the upper 250 m., which was shown above to be a good indicator of changes in flow, was used to select the position of surface gill net sets relative to the major currents. Salmon catches were compared with current systems and with the distribution of temperature.

Currents and Sockeye Salmon

The extent of the Alaskan Stream and the Subarctic Current were compared to the number of sockeye salmon caught in each gill net set during autumn, 1965 (fig. 6). The relatively high catches of sockeye salmon all occurred in the transition area of weak westerly or easterly flow between the Alaskan Stream and the Subarctic current.

Temperature Distribution and Salmon

Closely spaced bathythermograph observations indicated considerable variation in details of the temperature distribution along long. 173° E. and lat. 50° N., but major structures were generally continuous and were separated by definite boundaries. The number of sockeye salmon and the total

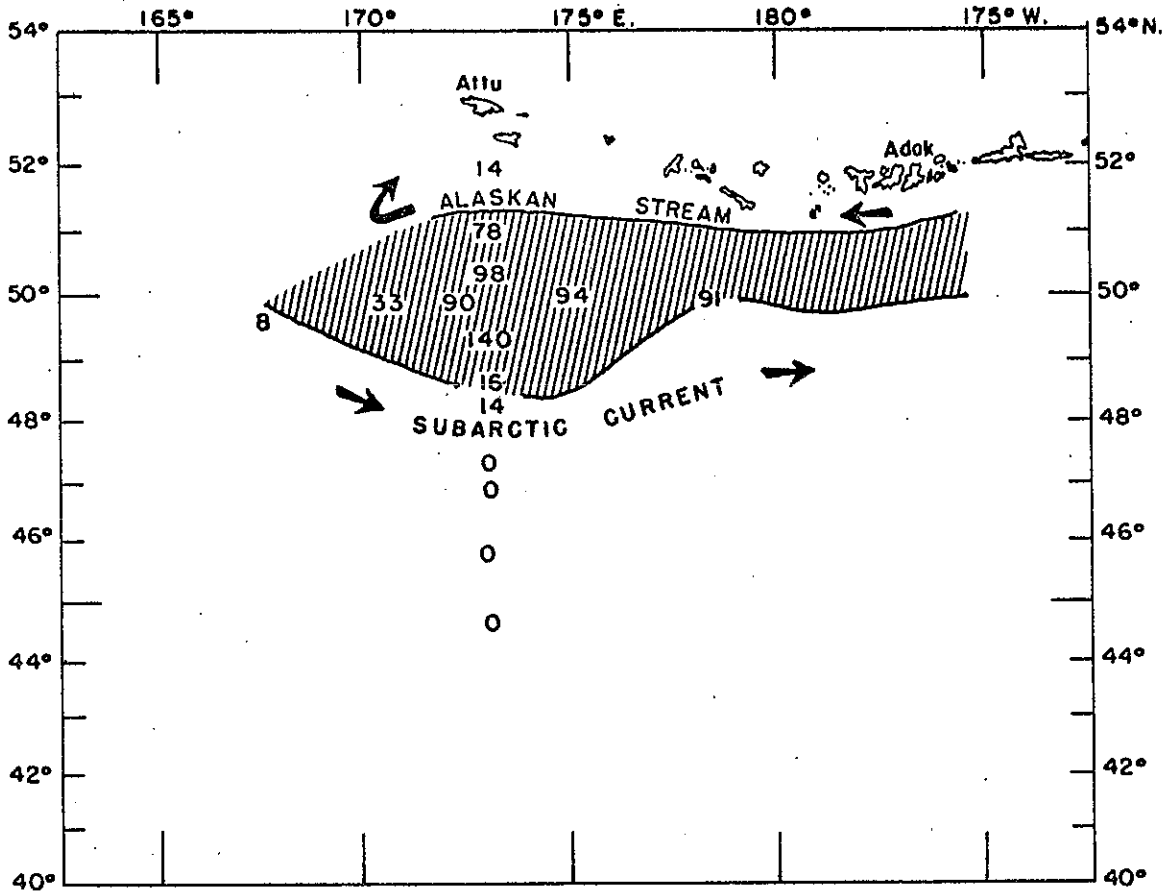

Figure 6.--Current distribution and the number of sockeye salmon caught in gill net sets, October and November 1965. Shaded area indicates area of weak currents between the Alaskan Stream and Subarctic currents.

number of salmon caught in surface gill net sets were about the same in water with the same temperature structure between 60 and 200 m., but the salmon catch changed composition or magnitude in zones with different structures.

The following general relationships were observed along long. 173° E. (fig. 7): (1) the salmon catch was low in the warm (> 4.0° C. below 100 m.) water near shore and composed mostly of sockeye salmon; (2) the salmon catch was high in the ridge area and composed mostly of sockeye salmon; (3) low catches (mostly chum salmon) occurred in the temperature-minimum; (4) no sockeye salmon were present at the southern boundary of the temperature minimum; and (5) the total salmon catch in the transition area was negligible.

Similar relationships were found along lat. 50° N. (fig. 8) with the exception of the large catch at long. 178° E.; the latter was associated with the northern boundary of the temperature-minimum. A low catch at long. 168° E. within the temperature-minimum, and several large catches within the ridge area, reflect the same relationships found along long. 173° E.

SUMMARY

The cruise of the RV George B. Kelez in the central North Pacific Ocean during October and November 1965 was the first cruise specifically designed to investigate the distribution of immature salmon in relation to the major oceanographic features of the Subarctic Region.

The locations of the axes of the major current systems and the major features of the distributions of temperature and salinity which were known prior to the cruise to be relatively constant again were not significantly different during autumn 1965. The distribution of temperature was obtained in considerably more detail than during previous fishery-oceanography

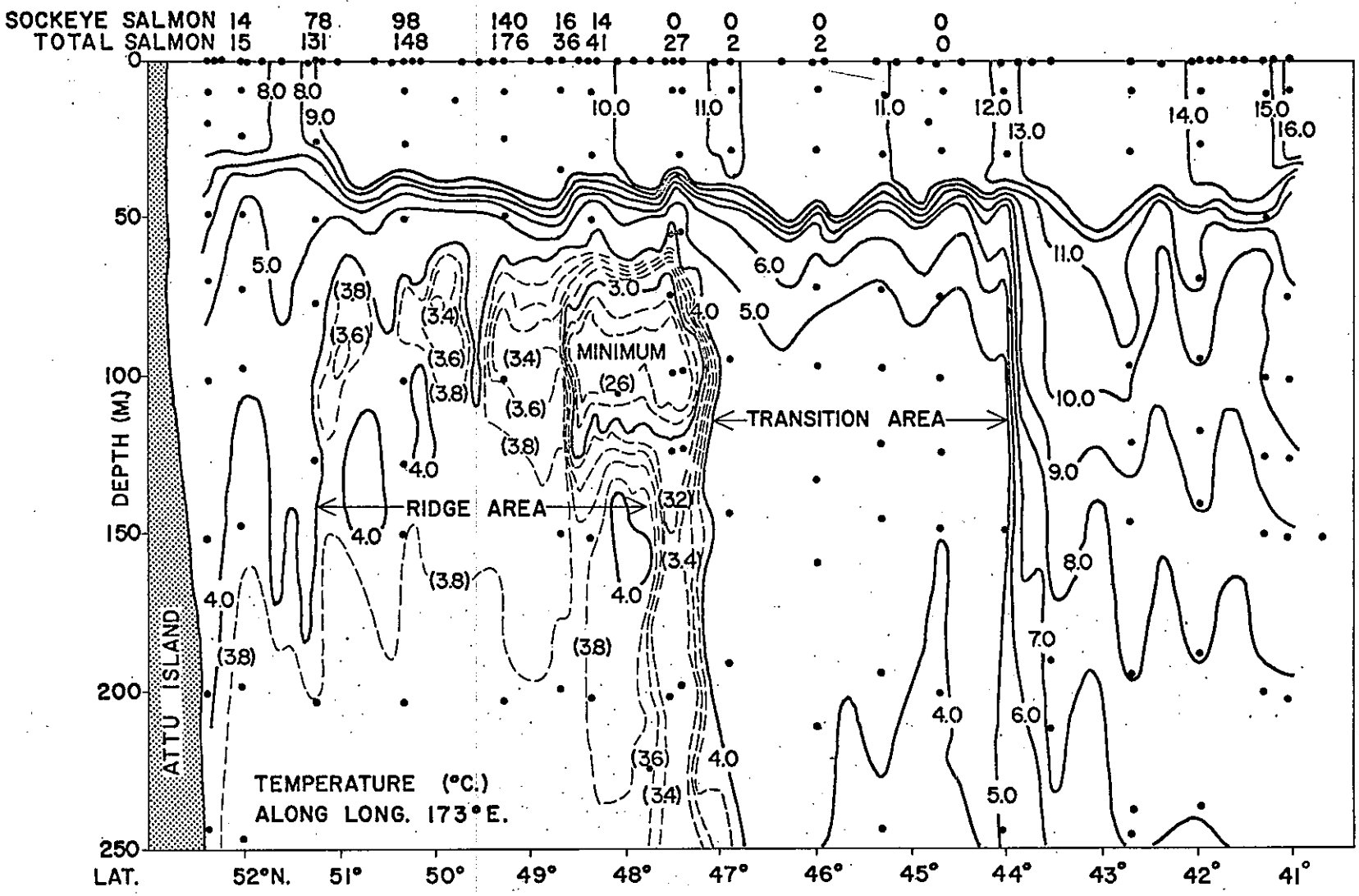

Figure 7.--Vertical section of temperature (°C.) along long. 173° E. and the number of salmon caught in surface gill net sets, October 2-16, 1965.

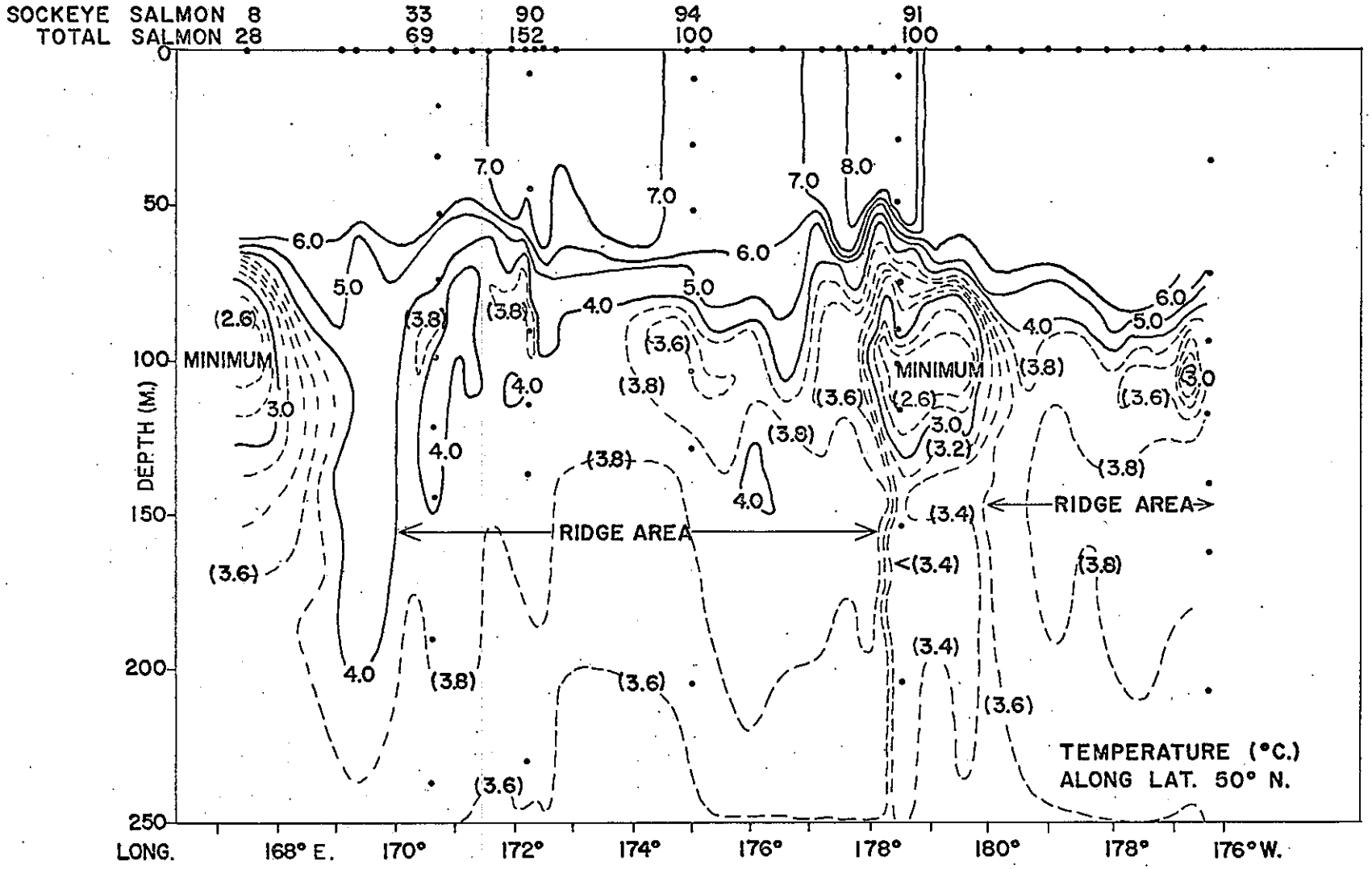

Figure 8.--Vertical sections of temperature (°C.) along lat. 50° N. and the number of salmon caught in surface gill net sets, October 23 to November 7, 1965.

cruises by closely spaced BT observations, and surface gill net sets were positioned within each water mass which had a different temperature structure between the depths of 60 and 250 m. The salmon catch in surface gill net sets was very consistent in areas with the same temperature structure but was different in magnitude or species composition in areas with different temperature structures.

An area of high relative abundance of sockeye salmon appeared to be related to the extent of the major current systems. Large catches were found in the area of weak currents between the axes of the westward flowing Alaskan Stream and the eastward flowing Subarctic Current.

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